Nitrogen balances in Dutch organic greenhouse production

Cuijpers, W.J.M.[1], Burgt, G.J.H.M. van der[2], & Voogt, W.[3]

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Abstract

The organic greenhouse production in the Netherlands is limited with regard to the number of growers, but plays an important role in EU organic greenhouse production. In the high-technology greenhouses a high production level is realized but nitrogen balances of this production system have been questioned. In order to document and improve the nitrogen balance, the production of seven greenhouses was monitored and soils were repeatedly analysed. The model "Bemestingsrichtlijn biologische kasteelten" (Fertilization Guide Organic Greenhouse Production) has been developed to simulate nitrogen availability and to fine-tune manure applications to crop demand. In the course of four years the overall nitrogen surpluses decreased sharply, but due to the observational character of the research no statistical analyses can be made. Part of the high surpluses in the first years can be explained by initial investments in soil organic matter. Calculation of the dynamic balance gives more possibilities to fine-tune farmers' fertilization strategies. Growers that followed the model-based advise for manure application, realized a substantial reduction of nitrogen surpluses.

Introduction

Although limited in number of growers, the Dutch organic greenhouse production is an important factor in Dutch and EU greenhouse production. Part of it is performed at a high technology level, resulting in correspondingly high nitrogen inputs and high production. The nitrogen balances of these production systems are undocumented so far. In a four-year monitoring project, the organic greenhouse production and fertilizer strategies of seven greenhouses were followed. During the project, a model was developed, tested and applied, aimed at the reduction of nutrient surpluses (nitrogen, phosphorus and potassium) of this production system. In the following text we focus on nitrogen only.

Materials and methods

Seven Dutch organic growers with intensive year-round cultivation of greenhouse crops participated in this monitoring project. From each greenhouse, one compartment was monitored from 2002–2005. During this period sweet pepper was cultivated most (43%) followed by tomatoes (39%) and cucumbers (18%). Total fresh- and dry mass of fruits, leaves and stems was determined throughout the growing period for each crop. Dry matter samples were analysed for nitrogen content. The total uptake of

[1] Louis Bolk Instituut, Hoofdstraat 24, 3972 LA Driebergen, Netherlands, E-Mail w.cuijpers@louisbolk.nl, Internet www.louisbolk.nl

[2] As above

[3] Wageningen University and Research Centre, Greenhouse Horticulture, Bleiswijk, The Netherlands

nitrogen for each crop was calculated. All compost, manure and additional organic fertilizer applications were registered, and total and mineral nitrogen contents were analysed if unknown. Additional organic fertilizers were applied as side dressings (e.g. feather meal pellets or beet vinasse) during the growing season. During the growing seasons, soil mineral N was measured at approximately one-month intervals (8-11 measurements per year). Additionally, in 2004 (two growers) and 2005 (seven growers) a compartment of each greenhouses was divided in two parts with different fertilization strategies, one receiving fertilizers according to the current growers' practice, the other receiving fertilizers according to the outcome of the model calculation. Data were analysed in two ways:

1. Calculation of the input-output balance, defined as the difference between total N-input (N-contents of organic fertilizers) and total N-output (N-contents of harvested products and above-ground crop residues).

2. Calculation of the dynamic balance, defined as the difference between total mineral nitrogen, becoming available during the growing season (including N-mineralization of soil organic matter, organic fertilizers and above-ground crop residues), and total N-uptake by crops (including harvested products and above-ground crop residues). Available nitrogen was estimated, using model calculations of the "Bemestingsrichtlijn Biologische Kasteelten" (Fertilization Guide Organic Greenhouse Production). This model has been developed to support Dutch organic greenhouse production (Voogt, 2005).

Results

For all crops, the input-output and dynamic balances for nitrogen were calculated (Cuijpers et al., 2007). There was a large variation between the growers and between years and crops (data not shown). This, together with the limited number of participants (n = 7) complicates interpretations of the results.

For further analysis of these data, the average of the input-output balance and dynamic balance of all crops within one year is given (table 1). A clear declining trend is visible in the input-output balance, but must be nuanced by two factors. First, the character of the research was observatory, not experimentally, which impedes statistical analysis. Second, nitrogen surplus might be crop-dependent and each year the 7 growers cultivated a different ratio of sweet pepper, tomato and cucumber. In the dynamic balances the variation among the growers and among the years is too big to conclude that the surplus has diminished over the years.

Tab. 1: Total nitrogen crop uptake and nitrogen surplus in both input-output balance and dynamic balance (between brackets: lowest and highest value). Data given in kg ha^{-1}, n = 7

Year	Total crop uptake	Surplus Input-output balance	Surplus Dynamic balance
2002	**763** (452/1263)	**711** (215/2667)	**274** (-47/596)
2003	**638** (371/1012)	**460** (254/747)	**448** (182/684)
2004	**781** (382/1179)	**151** (-507/681)	**213** (-236/584)
2005	**765** (584/976)	**78** (-389/898)	**173** (-61/497)

In table 2, the improvements, achieved by application of the fertilization model are shown for both input-output balance and dynamic balance. In 2005, three out of seven growers adapted their fertilization strategies completely to the model strategy. In the other greenhouses the use of the model reduced nitrogen surplus in both input-output balance and dynamic balance, with exception of one grower. In this greenhouse compartment the model-directed manure strategy seemed to show nitrogen shortage and side-dressings were applied above the recommended amount. No yield effect was recorded due to reduced nitrogen applications.

Table 2. Reduction of applied and available nitrogen (kg/ha) as a result of the use of the fertilization model

Grower	Reduction in N-application Input-output balance	Reduction in N-availability Dynamic balance
A (2005)	0	0
B (2005)	0	0
C (2005)	176	17
D (2005)	1079	321
E (2004)	482	298
E (2005)	104	168
G (2005)	-301	-327
N (2004)	582	349
N (2005)	0	0

Discussion

In the input-output balances the input data can be considered as reliable. However, the output data are influenced by some methodological uncertainties. Calculation of the nitrogen quantities in fruits and other plant material is based on irregular measurements during the growing season. The amount of leaves, fallen or cut during growing cycles, were partly measured, partly estimated. Crop residue dry matter was based on measurements of only five plants at the end of the cropping period, as were nitrogen contents. All these factors increase the possible variation in outcome.

The dynamic balances contain more uncertainties than the input-output balances. The mineralization of organic matter and thus the release of nitrogen is calculated according to Janssen (1984) by means of the parameter *Initial Age* (IA), which is based on the C-turnover rate. The IA of organic inputs were based on incubation tests that were carried out on 42 different organic fertilizers in 2002 and 2004. The IA of soil organic matter was calculated based on incubation tests, carried out in 2002 and 2004) (data not shown).The model setup uses soil organic matter with an IA which is (in this case) derived from incubation experiments and it uses actual and historical manure applications. An overlap exists between IA of soil and historical manure applications. This was arbitrarily corrected, as was corrected for (a) length of growing period of the crops and (b) mineralization of nitrogen from fallen or cut leaves during growth. Even given these uncertainties, the dynamic balance offers more possibilities to fine-tune farmers' fertilization strategies and to gain insight in soil processes with environmental importance, like leaching or denitrification.

The average-year results of the in-out balances (table 1) show a clear decline in nitrogen surpluses, although the results must be interpreted carefully as was stated before. The decrease can partly be explained by unusual high applications of compost (200 tons ha^{-1} or more) and manure at the beginning of this 4-year period, motivated by the growers as an investment in soil organic matter. This is supported by a measured increase of soil organic matter (data not given). Such an application is done only once or twice, and will result in a long-term effect of increased nitrogen release out of soil organic matter. This will diminish the need for manure application in the following years. Modelling the soil organic matter dynamics with the NDICEA model (Van der Burgt et al., 2006) indicates that a yearly application of 50 tons ha^{-1} of compost will maintain soil organic matter in a range around 6%, a level which is considered to be sufficient. Interpreting the data, it should be taken into account that N-losses by denitrification, or by leaching were not part of the balance calculations. For situations with significant over-irrigation it could have the effect that the soil mineral N is reduced, both by higher denitrification rates and N leaching, stimulating the growers to additional side dressings.

Conclusions

Although observational data are not statistically analysed, the sharp decline in nitrogen surplus in the input-output balance is convincing and can be explained. The high nitrogen input in the first years is not lost; it is part of the build-up of soil organic matter.

The dynamic balance is a much more interesting instrument for analysing nitrogen balances than the input-output balance, even knowing the uncertainties linked to the dynamic balance and the more complicated way to construct it. Together with a (still to be validated) model, this can be a promising decision-support instrument for greenhouse growers to meet future challenges in further improvements of nitrogen balances.

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